

## The Intragranular Textures of Aggregates and its Correlation to the Physical Properties

(Tekstur dalaman Butiran dalam Agregat dan Perkaitannya dengan Sifat Fizikal)

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### ABSTRACT

*To evaluate the correlation of the intragranular textures on the physical properties of coarse aggregates, four aggregates samples consisting of three granitoid sources and one limestone have been studied. The role played by intragranular textures (mineral assemblage, grain size and grain boundaries) in influencing the physical properties are potentially significant to the fact that such textural variation may complicate the aggregate strength. This study indicates that the aggregates exhibited variation in textural habits. The granitoid aggregates, which is rich with silicate composition has typical heterogranular textures of porphyritic and equigranular grain structures. Whereas the limestone aggregate comprises of bioclast and peloid allochems cemented by micrite and spar. The granitoid aggregates showed better dispersed characters and had extremely interlocking crystal boundaries which have more physical strength compared to a carbonate aggregate.*

**Keywords:** Aggregate; physical properties; textures

### ABSTRAK

*Untuk menilai perkaitan antara tekstur dalaman butiran terhadap tabii fizikal bahan agregat, empat sampel agregat yang terdiri daripada tiga sumber granit dan satu batu kapur telah dikaji. Fungsi tekstur dalaman butiran (himpunan mineral, saiz butiran dan sempadan butiran) dalam mempengaruhi sifat fizikal, berupaya secara signifikan kepada situasi kepelbagaian tekstur yang merumitkan kekuatan agregat. Hasil kajian ini memperlihatkan bahan agregat yang dikaji menunjukkan kepelbagaian pencirian tekstur. Agregat granitoid yang kaya dengan komposisi silikat mempunyai tekstur heterobutiran tipikal iaitu porfiritik dan struktur butiran sama saiz. Sementara itu, agregat batu kapur yang mengandungi bioklas serta alokem peloid disimen oleh mikrit dan spar. Bahan agregat granitoid mempamerkan ciri yang lebih terserak, dan sempadan butiran yang amat saling-mengunci, mempunyai kekuatan fizikal lebih berbanding agregat karbonat.*

**Kata kunci:** Agregat; sifat fizikal; tekstur

### INTRODUCTION

Rock aggregates are used as a fundamental component in many fields of construction throughout the world, including concrete, road works, backfill, drainage and sewage treatment. The potential durability of an aggregate in a specific end-use application is often determined by its basic characterisation. According to previous published works reported by Akeson et al. (2001), Al-Harthi (2001), Azimah (2006) and Pikriyl (2001), key characteristics such as petrographical, geochemical and physical properties of aggregates have a controlling effect on a specific engineering application.

Natural aggregates were generally extracted from larger rock formations through an open excavation. Crushed aggregate was then produced by crushing the extracted rock boulders, cobbles, or large-size gravel to useable sizes by mechanical crushing. In fact, different rock sources may lead to the production of aggregate with miscellaneous characteristics. From this initial

understanding, it has been realized that the variation of natural aggregate sources requires a profound knowledge of the parent rock properties. This paper describes results of a study whose aim was to examine the role of intragranular textures in influencing the physical behaviour of the aggregates.

### MATERIALS AND METHODS

Four sources of aggregate were used as normal weight coarse aggregate in this study. These four sources consisted of (1) Shap granite from the Lake District, UK, (2) Mountsorrel granite from Leicestershire, UK, (3) Johor granite from Johor, Malaysia and (4) Coldstones limestone from North Yorkshire, UK. The three granitic sources were intended to cover a variety of granitic aggregates commonly used in the concrete fabrication industry. The physical appearance of all four types of aggregates is shown in Figure 1.

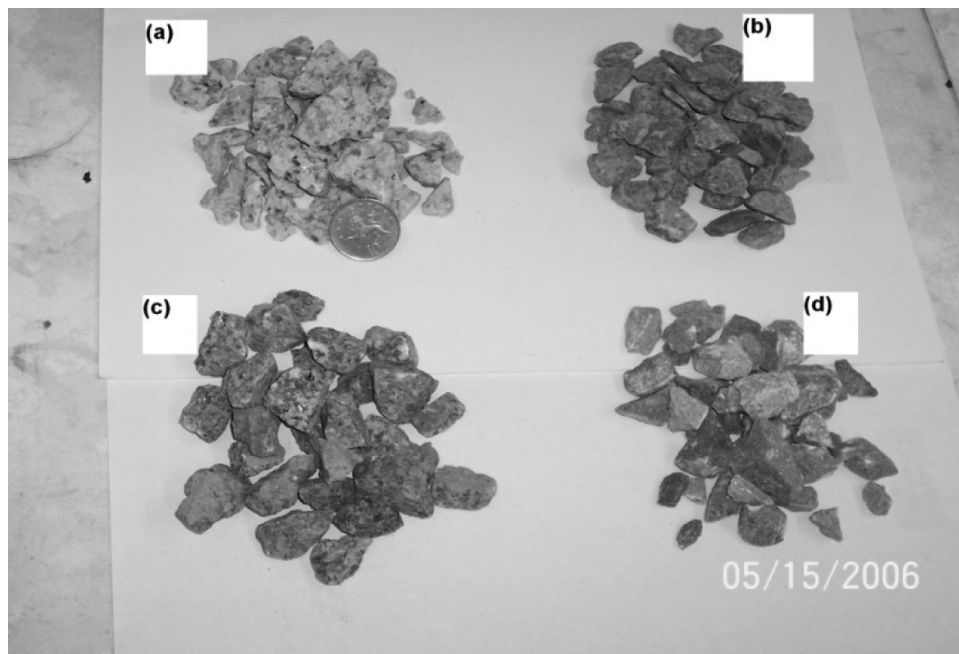


FIGURE 1. Four different varieties of aggregates used in this project. (a) Johor granite, (b) Mountsorrel granite, (c) Shap granite and (d) Coldstone limestone

The following characterization tests were conducted on each type of aggregate; petrographic analysis, grading by sieve analysis (BS 410.1:2000), specific gravity and absorption (ASTM C127 and C128 : Kent 2000) and the aggregate impact value (AIV) test specified to BS812-112.

## RESULTS AND DISCUSSION

### PHYSICAL APPEARANCE

Shap aggregate is a crushed and angular aggregate. Most of the particles have a hard, dense and rough coarse texture. The matrix is massive, composed largely of smokey quartz, white plagioclase feldspar and black biotite mica. Generally, the edges of the particles are still quite sharp, but some large particles have been found to have a smoother edge after washing and grading. Mountsorrel granite is a crushed aggregate with angular shape and has sharp edges. This aggregate is composed of a great variety of particles that appear dense, very hard, rough and pink-grey in colour. When washing, the microfines fraction was simply removed and it was found that this group also consisted of a small percentage of elongated particles.

The Johor granite is also a crushed aggregate, angular, very hard, dense and the lightest in colour compared to the rest of the specimens. Most of the particles have a rough surface texture and show sharpened edges. It is composed of minerals with non-phorpyritic fabric and no particles show a flat or elongated shape. The Coldstone aggregate appears as grey coloured particles with a rather soft and smooth surface. Due to its softness, the edges of some large particles have been smoothed during handling and

are not very sharp. Regarding the shape, this aggregate has a combination of elongated, rough, round and smooth particles.

### SIZE GRADING

In the case of the current study, the overall grading of the coarse aggregates showed a consistent grading character. Figure 2 illustrates that the grain size distributions of the aggregate in this research composed of mixed, well graded aggregates with particle size ranging from fine to 30mm maximum. Well graded aggregates will relatively minimise a gap grading or bleeding problem in concrete.

### INTRAGRANULAR TEXTURES

The intragranular texture of Shap granite (Figure 3) combines prominent large pink orthoclase megacrystalline phenocrysts, situated within a finer-grained white-brown groundmass of plagioclase, quartz, orthoclase and biotite, the whole being an example of the rock matrix type known as a porphyry. The orthoclase phenocrysts were evenly distributed throughout the rock and were frequently up to 5 cm in length. Individual megacrysts also displayed some Carlsbad twinned extinction. On the other hand, plagioclase in the ground mass occurs as euhedral crystals, often showing lamellar albite twinning and indications of being partially altered.

The petrography of the Mountsorrel granite clearly shows typical features of the intergranular granitic crystalline texture (Figure 4). The mineralogical composition is mainly K-feldspar orthoclase, plagioclase, quartz and biotite. The mineralogical components of this granite can be classified as having a same-sized texture,

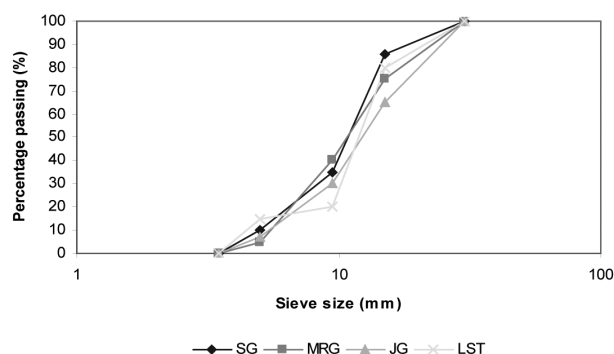


FIGURE 2. Grading of coarse aggregates used in this study. SG (Shap granite), MRG (Mountsorrel granite), JG (Johor granite) and LST (Coldstones limestone)

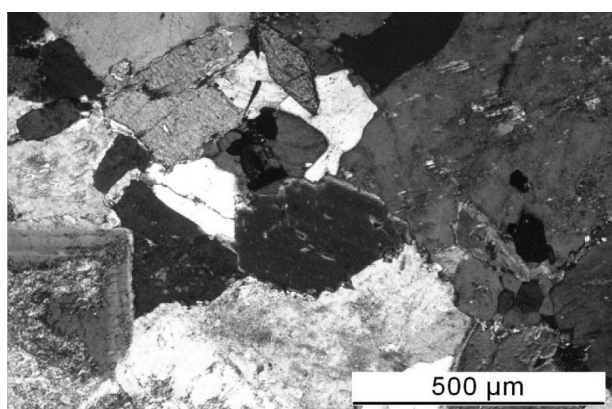


FIGURE 3. Cross polarized view of Shap granite. Typically hard, hypocrySTALLINE, medium to coarse grain, sub-anhedraL crystals, Straight grain boundaries in some minerals but mostly show uneven interlocking bonding texture

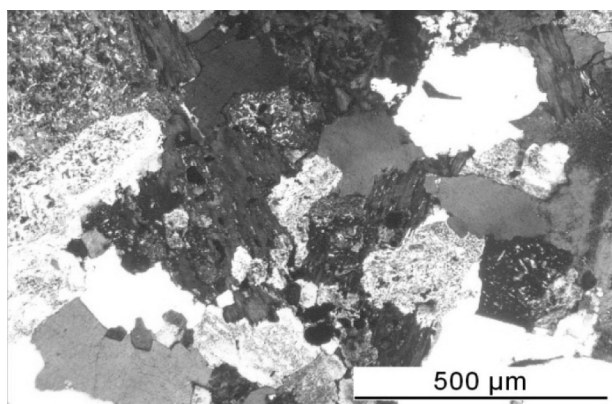


FIGURE 4. Mountsorrel granites. Hard, hypocrySTALLINE, coarse grain, elongated and very angular crystals, interlocking texture with tight grain boundaries

as all minerals were found have no significant variation in grain size. Apart from the main components, accessory minerals such as epidote and oxides were also present in very small percentages.

The Johor granites has the lightest colour in terms of macro appearance when compared to the other samples.

This appearance is related to the occurrence of leucocratic minerals such as quartz, K-feldspar and plagioclase. Thin section studies of the Johor granite proved that 90% of the total composition was mainly made up of those felsic minerals. Other mafic minerals such as biotite are also present. Figure 5 illustrates the general petrographic texture of the Johor granite sample. AnhedraL quartz grains were found with a grain size varying from 2 mm to 10 mm and dominating the total percentage of the felsic minerals.

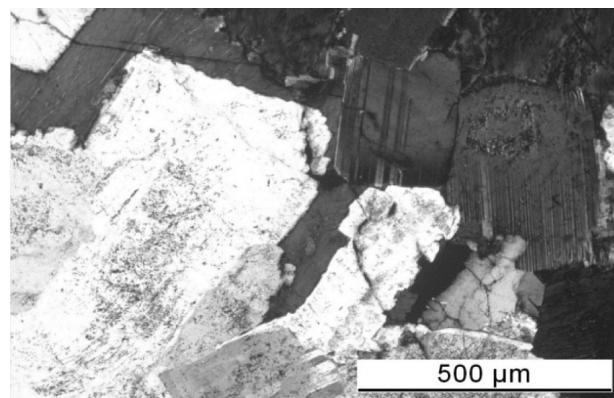


FIGURE 5. Very hard, hypocrySTALLINE, angular and mostly anhedraL crystals, Most of the minerals show very tight crystal boundaries which may contribute to the extremely strong bonding texture

Generally, the texture of the Coldstone limestone is the result of four important carbonate components of bioclast and peloid allochems cemented largely by micrite and microcrystalline spar. This limestone is identified as having peloids as the largest proportion of the allochems and such grains are mainly circular in cross-section. The remainder of the rock comprises a mixture of micrite (a mixture of carbonate mud sediments) and spar cement. Based on the textural classification scheme by Dunham (1962) as shown in Figure 6, this limestone can be classified as packed biomicrite.

Detailed petrographic inspection in this research also suggests that the three granitic sources varied in textural habits. Although all granitic samples showed a typical magmatic heterogranular texture, the average grain sizes were slightly different. Shap granite appears as having a porphyritic grain assemblage while Johor and Mountsorrel granite exhibit equigranular coarse grained texture.

#### PHYSICAL PROPERTIES

The physical properties determined for the coarse aggregates used in this research are shown in Table 1. In general, the granitic aggregates exhibited quite similar values of relative density that are typical for granitic rocks, with average relative density values of 2570 to 2670 kg/m<sup>3</sup>, whereas the limestone's average density was 2160 kg/m<sup>3</sup>. Johor granite exhibited a higher value than those obtained



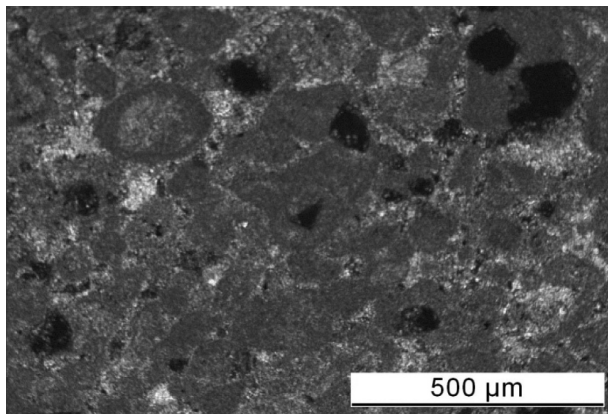


FIGURE 6. Soft, porous, composed mainly of peloid crystalline grains, but cemented by fine crystalline micrite, grain loose and weakly bonded

for the other aggregates. The lowest density displayed was limestone and this reflects its less dense nature. It is possible to consider the granitic aggregates in this study as low porosity rocks, but the Coldstones limestone exhibits a significant porosity value. Consequently, the limestone also has the highest water absorption percentage.

The aggregate impact values (AIV) obtained from samples can be considered as significant in determining the strength of the aggregate under repeated or continuous impact. According to Dhir et al. (1971), a numerically lower result indicates a higher resistance of the aggregate during the test. It is apparent from Table 1 that Johor granite has the lowest AIV and Coldstones limestone shows the highest.

The microscopic analyses in this study also revealed a slight heterogeneity of the contact nature between the mineral grains in each specimen. Although the methods used are qualitatively based, it is possible to predict their mechanical behaviour. Texture parameters such as the degree of grain interlocking and mineral contact plays an important role in the mechanical properties (Howarth & Rowlands, 1987; Akesson et al. 2001).

Observations suggest that Johor granite showed better dispersed characters, and had extremely interlocking crystal boundaries compared to Mountsorrel and Shap granite. This interpretation is mainly influenced by the irregularity of the grain boundaries and the dispersion of the mineral phases. The boundaries were often found between different

phases (e.g quartz-feldspar) and according to Akesson et al. (2001), the same phases (e.g quartz-quartz) are likely to form mechanically weak discontinuities. Things differ slightly in Shap granite, which mostly still shows an interlocking texture, but the mineral phases have a wide size range between phenocrysts, the largest and matrix, the smallest particles.

There is an indication that a diminishing grain size causes a slight decrease in the impact value of the granitic aggregates. Shap granite which is composed of non-equigranular grains with mega-sized alkali feldspar phenocrysts has the highest ACV value amongst the three granitic sources. This suggests that the resistance of the granitoid rocks to the effect of impact increases slightly with decreasing grain size. This finding agrees with work by Miskovsky et al. (2004), which pointed out the main factors which influence the granitoid aggregate mechanical properties. Different petrographic properties such as grain size, mineral dispersion and texture would have an influence on the mechanical properties (e.g ACV, ACV and strength).

The results of this petrographic analysis can be used to predict the aggregate mechanical properties. Raisanen (2004) suggested new details for the relationship between grain size and mechanical properties. The coarser feldspars have a controlling influence on the grain size distribution and this evidently weakens the mechanical properties of these samples. This suggestion seems to be correct in the case of Shap granite in this study, where alkali feldspar is present mostly as mega-sized phenocryst grains compared to the other two granitic sources. According to Al-Oraimi et al. (2006), aggregates with high perimeter values have the best resistance to fragmentation and abrasion. A high perimeter corresponds to fine-grained rocks where the minerals occur as individual grains, rather than monomineralic aggregates. An increase in grain size and the formation of mineral aggregates of the same phase have a negative effect on the quality of the rock, but this is not significant in the case of Coldstones limestone in this study. Although this limestone has very fine compacted carbonate grains, it shows less resistance to continuous impact. This may be due to the hardness of the minerals, as calcite makes up 95% of its composition. Based on the Mohs hardness scale, calcite has a hardness value of 3 compared to feldspar (6) and quartz (7).

TABLE 1. Physical properties of aggregates

Physical properties	Aggregate Type			
	Mountsorrel granite	Shap granite	Johor granite	Coldstone limestone
Relative density (kg/m <sup>3</sup> )	2570	2600	2670	2160
Water absorption (%)	0.6	0.5	0.5	1.5
Porosity (%)	0.6	0.7	0.2	2.8
Aggregate Impact Value (AIV)	17	19	14	24

The physical properties of coarse aggregates are also associated with the rock deterioration state (weathering) from where they come (Torgal & Castro-Gomes 2005). Alteration mechanisms lead to internal breaking that promotes weathering and material loss due to dissolution or internal erosion. Minor alterations were found in the tested aggregates. For granitic aggregates, the initial alteration process is only exhibited by the presence of the altered plagioclase twinning. As well as those characteristics which indicate rock alteration, there are others, which indirectly are a consequence of the first ones such as density, mechanical resistance and permeability (Kazi & Al-Mansour 1980). In general, all the tested aggregates in this study are physically strong and less absorptive.

### CONCLUSION

The results of this study show that granitic resources rich with a silicate composition have more physical resistance compared to a carbonate rich aggregate. The variation in the mineral composition may also reflect changes in the texture of the aggregates from the same class. For instance, the Johor granite which contained equigranular grains with very tight boundaries was found to be harder when compared to Shap and Mountsorrel granites. The initial characterisation of aggregates used in this study has led to the following concluding remarks: (1) The present study shows how qualitative petrographic examination of aggregates using optical microscopy helps to describe petrographic properties and to interpret the results of physical testing. (2) Composition, texture, size and shape of minerals have an affect on the mechanical properties of aggregates, as well as petrographic properties. (3) In the granitic aggregates, the grain size variation affected the resistance of the aggregates to impact. Aggregates with equigranular grains were more resistant than those with non-equigranular grains. (4) The results of Aggregate Impact Value (AIV) measurements indicated that granitoid aggregate were stronger than limestone resources. (5) The physical properties of the aggregates are a function of the mineralogical and textural characteristics.

### REFERENCES

- Akesson, U., Lindqvist, J.E. & Goransson, M. 2001. Relationship between texture and mechanical properties of granite, Central Sweden, by use of Image-Analysing Techniques. *Bulletin of Engineering Geology and The Environment* 60: 277-284.
- Al-Harthi, A.A. 2001. A field index to determine the strength characteristic of crushed aggregate. *Bulletin of Engineering Geology and The Environment* 60: 1-14.
- Al-Oraimi, S.K., Taha, R. & Hassan, H.F. 2006. The effect of the mineralogy of coarse aggregate on the mechanical properties of high-strength concrete. *Construction and Building Materials* 20: 499-503.
- Azimah, H. 2007. Mineralogy and geochemistry of rock aggregates and their relation to the interfacial transition zone (ITZ) in concrete. PhD thesis. University of Leeds.
- Dhir, R.K., Ramsay, D.M. & Balfour, M. 1971. A study of the aggregate impact and crushing value tests. *The Journal of The Institution of Highway Engineers* Nov: 56-61.
- Dunham, R.J. 1962. Classification of carbonate rock according to depositional texture. Classification of carbonate rocks. *Ham W.E. ed. Ame. Assoc. Pet. Geol. Mem.* 1: 108-121
- Howarth, D.F. & Rowlands, J.C. 1987. Quantitative assessment of rock texture and correlation with drillability and strength properties. *Rock Mech Rock Eng.* 20: 57-85.
- Kazi, A. & Al-Mansour, Z.R. 1980. Influence of geological factors on abrasion and soundness characteristics of aggregates. *Engineering Geology* 15: 195-203.
- Kent, I. 2000. *Engineered concrete. Mix Design and Test Method.* London: CRC Press.
- Miskovsky, K., Taborda, D.M., Kou, S.Q. & Lindqvist, P.A. 2004. Influence of the mineralogical composition and textural properties on the quality of coarse aggregates. *Journal of Materials Engineering and Performance* 13(2): 144-150.
- Pikriyl, R. 2001. Some microstructure aspects of strength variation in rocks. *Int. Jour. of Rock Mechanics and Mining Sciences* 38: 671-682.
- Raisanen, M. 2004. Relationships between texture and mechanical properties of hybrid rocks from the Jaala-litti complex, Southeastern Finland. *Engineering Geology* 74: 197-211.
- Torgal, F.P. & Castro-Gomes, J.P. 2006. Influence of physical and geometrical properties of granite and limestone aggregate on the durability of a C20/25 strength class concrete. *Construction and Building Materials* 20(10): 1079-1088.

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